HIGHER TEST PAPERS IN CHEMISTRY

HOLMYARD

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IN
CHEMISTRY

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EXHIBITIONS EXAMINER AND SENIOR MATRICULATION EXAMINER (CHEMISTRY) AT THE UNIVERSITY OF LONDON
EXAMINER IN CHEMISTRY (HIGHER CERTIFICATE) FOR THE JOINT MATRICULATION BOARD OF THE UNIVERSITIES OF MANCHESTER, LIVERPOOL, LEEDS, SHEFFIELD AND BIRMINGHAM
HON. FOREIGN EDITOR, ARCHIVIO DI STORIA DELLA SCIENZA
MEMBER OF THE ROYAL ASIATIC SOCIETY AND OF THE MEDIAEVAL ACADEMY OF AMERICA

LONDON
SIR ISAAC PITMAN & SONS, LTD.
PARKER STREET, KINGSWAY, W.C.2
BATH, MELBOURNE, TORONTO, NEW YORK
1928

PREFACE

In preparing the six hundred questions which follow, the characteristic features of Higher Certificate, Intermediate, and University Scholarship Examinations have been carefully studied, and subjects which appear to be most frequently demanded have been allotted a correspondingly large number of questions. Two very noticeable points in recent papers have been the rarity of numerical problems and the fact that those which have been set are as a rule extremely easy. It was therefore considered that the inclusion of a large number of such questions in the present book was not appropriate, particularly as most textbooks of chemistry give quite sufficient for the purpose.

Another tendency has been to give candidates some opportunity of showing what knowledge they possess of chemical history and of the work of the great chemists ; a few historical questions have consequently been included. Lastly, the University Scholarship Examinations usually have a general paper, in which science candidates find questions requiring a reflective power which not all of them, perhaps, have had adequately tested previously. For this reason, a small number of questions on the simpler philosophy of science will be found in certain of the Test Papers.

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HIGHER TEST PAPERS IN CHEMISTRY

No. 1

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Give a description of the phenomena which certain elements exhibit in the "nascent" state. What explanations have been suggested to account for these phenomena ?

2. Write a short account of the phenomena of flame and combustion.

3. Give a short account of the metallurgy of lead and of the oxides and chlorides of the metal.

4. Write a historical sketch of the isolation of fluorine. Compare and contrast the properties of this gas with those of the other halogens.

5. "An extremely slight decrease in the percentage of carbon dioxide in the atmosphere would be sufficient to bring practically all terrestrial life to an end." Discuss and explain.

6. A certain gas is believed to be either (*a*) chlorine, or (*b*) a mixture of chlorine and nitrogen peroxide, or (*c*) a mixture of chlorine and bromine vapour, or (*d*) a mixture of chlorine, bromine vapour and nitrogen peroxide. How would you determine which of these four it is ?

No. 2

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. The ratio of the densities of oxygen and nitrogen is also the ratio of (*a*) their atomic weights, and (*b*) their molecular weights. Explain why this is so.

2. Write a short essay on the commercial applications of catalysis.

3. A solution contains hydrochloric, sulphuric and oxalic acids. Suggest a method of estimating the weight of each acid present in 1 litre of the solution.

4. Compare and contrast the properties of the chief compounds of iron with those of the chief compounds of (*a*) chromium, and (*b*) manganese. Given a supply of manganous sulphate, how would you prepare a specimen of manganese dioxide ?

5. Describe and explain the action of ammonia solution upon (*a*) mercurous chloride, (*b*) lead chloride, (*c*) silver chloride, (*d*) copper sulphate solution, (*e*) iodine.

6. Give an account of the oxides and oxyacids of phosphorus. Discuss the basicity of the acids.

No. 3

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Give, with full practical details, methods by which the following elements may be converted into their oxides: nitrogen, iodine, phosphorus, sulphur, silver, iron, arsenic, lead.

2. A certain solution was intended to be a decinormal solution of caustic soda, but it was found to contain a small quantity of sodium carbonate. How would you find the weights of caustic soda and sodium carbonate in 1 litre of the solution?

3. What do you understand by a *pure* substance? Describe the general methods of purifying (*a*) solids, (*b*) liquids, and (*c*) gases.

4. Explain the term *mixed crystals*. What reasons have we for believing that mixed crystals are mixtures and not compounds? Mention examples of substances which form mixed crystals.

5. How is hydrogen iodide usually prepared? How would you determine its heat of formation?

6. Explain and illustrate the terms oxidation and reduction. How are oxides classified? Classify the following oxides, giving your reasons in full: H_2O, CO, CO_2, NO_2, N_2O, NO, Fe_3O_4, Pb_2O.

No. 4

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. "Matter is indestructible." Discuss.

2. What differences in physical properties would you expect to find between solutions of potassium nitrate and cane-sugar, containing one G.M.W. in 10 litres ? Give your reasons in full.

3. Given a definite weight of litharge, how would you obtain from it as much as possible of each of the two elements it contains ?

4. Describe the commercial process for the preparation of sodium. What are the principal industrial uses of this metal ?

5. How is potassium ferrocyanide made, and what are its chief properties ? Explain the fact that it does not answer to the usual tests for iron.

6. Describe and explain the action of the halogens upon solutions of sodium thiosulphate. How is the latter substance prepared commercially, and for what purposes is it used ?

No. 5

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Discuss the value of Le Chatelier's theorem. Deduce from this theorem the effect of changes of pressure upon (*a*) the freezing-point of water, (*b*) the freezing-point of mercury, and (*c*) the boiling-point of alcohol.

2. How would you estimate the ratio by weight of chlorine as chlorate to chlorine as chloride, in a solution containing unknown amounts of potassium chlorate and potassium chloride ?

3. Iron is said to form two series of compounds, the ferrous and ferric. Explain the meaning of this statement and describe evidence to support it.

4. Describe the preparation and properties of cyanogen, and explain the reasons for assigning the formula C_2N_2 to its molecule.

5. How is hydrazine prepared ? What are its principal properties, and how has its formula been established ?
Compare and contrast the hydrides of phosphorus with those of nitrogen.

6. Translate and comment upon : Das in der Natur vorkommende Wasser ist niemals ganz rein, da es immer mit anderen Stoffen in Beruhrung kommt und diese teilweise auflöst. Die Darstellung „ absolut " reinen Wassers ist eine Unmöglichkeit, da man eben Gefässe irgendwelcher Art, aus denen sich immer etwas auflösen kann, nicht auszuschliessen vermag. Dagegen lâsst sich ein Wasser, das den meisten Prüfungen gegenüber sich als reines verhâlt, nicht allzu schwierig herstellen.

No. 6

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What is meant by *heat of neutralization*? Show that the basicity of a strong acid may be determined by thermal experiments.

2. State Henry's Law of Gas Solubility. The solubility of oxygen is 0·034 c.c. per c.c. at 15° C., and that of nitrogen 0·018 c.c. per c.c. at the same temperature. Find the proportions by weight of oxygen to nitrogen in air dissolved in water at 15° C.

3. Give some account of methods employed for the fixation of atmospheric nitrogen.

4. Give a short account of the metallurgy of tin, and of the oxides and chlorides of the metal.

5. Discuss the question of the constitution of bleaching-powder. How is bleaching-powder manufactured, and how would you estimate the available chlorine in it?

6. How do chlorine, bromine and iodine react with water, and under what conditions?

A liquid is known to be an aqueous solution of either (*a*) chlorine or (*b*) hypochlorous acid, or (*c*) chlorine and hydrochloric acid. How would you ascertain which of the three it is?

No. 7

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State, with all essential practical detail, how you would proceed to examine the spectrum of (*a*) a gas, (*b*) a metal, and (*c*) a metallic salt.

2. Discuss the evidence for the objective existence of atoms.

3. A given solution contains ammonium and barium chlorides. How would you estimate the weight of each substance in a litre of the solution ?

4. Give a short account of the metallurgy of iron and of the oxides and chlorides of the metal.

5. Until quite late in the nineteenth century, the celebrated French chemist Berthelot used the old formula HO for water. Give, in full, your reasons for preferring the modern formula H_2O.

6. Give some account of the hypotheses which have been put forward to explain the formation of sulphuric acid in the lead-chambers.

No. 8

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. The equivalent of nitrogen is 4·67, its atomic weight is 14, its molecular weight is 28, and its valency is 3. Explain the meaning of these terms, and describe both the experimental evidence and the theoretical arguments upon which the above numbers are based.

2. "Mercuric ions are poisonous; cyanide ions (CN') are poisonous. Mercuric cyanide does not ionize in solution; therefore it should be non-poisonous. It is poisonous, however, so the Ionic Theory is untrue." Discuss and criticize.

3. Describe some of the properties of water of crystallization. How would you determine the dissociation pressure of a hydrated crystalline salt?

4. Describe experiments to show that hydrogen peroxide and ozone are oxidizing agents. How has the formula for hydrogen peroxide been established?

5. How are the oxides of chlorine prepared? Mention their chief properties and state how the composition of any *one* of them has been established.

6. What do you mean by "degree of ionization"? How may the degree of ionization of an electrolyte in solution be determined?

No. 9

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. In organic chemistry, substances are often purified by distillation in steam. Discuss the principles upon which this method is based.

2. What is meant by a *cryohydrate* ? Illustrate your answer by reference to the phenomena observed on cooling a solution of common salt in water.

3. Write an essay upon that element which you consider to be most interesting from a chemical point of view.

4. Discuss from a chemical standpoint the manufacture and composition of the chief varieties of plain and coloured glass.

5. Describe the reactions of the common acids with aluminium and tin.

6. Describe and explain the action of sulphur dioxide upon solutions of the following substances : caustic soda, bromine, sulphuretted hydrogen, potassium perchlorate.

No. 10

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. How would you distinguish between (*a*) nitrous oxide and oxygen, (*b*) nitrogen peroxide and bromine vapour, (*c*) chlorine and chlorine peroxide, (*d*) carbon monoxide and methane ?

2. Carefully describe the action of heat upon potassium chlorate (*a*) when no catalyst is present and (*b*) in the presence of a catalyst.

3. Ferric oxide is said to act as a catalyst upon the decomposition of potassium chlorate by heat. How would you test the truth of this statement experimentally ?

4. How is oxygen obtained (*a*) chemically pure, and (*b*) on the commercial scale ? What are the principal industrial uses of oxygen ?

5. A certain specimen of zinc is suspected to contain arsenic as an impurity. What tests would you make to ascertain whether arsenic is present ?

6. State Hess's Law (Law of Constant Heat Summation), and explain its use in determining the heats of formation of compounds.

No. 11

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe experiments to show that ozone and nitric acid are oxidizing agents. How has the formula for ozone been established ?

2. Give some account of common indicators, and explain their action, and the purposes for which they are used, in terms of the ionic theory.

3. How is silicon fluoride obtained ? Mention the chief properties of this gas, and state how its formula has been established.

4. Describe the general methods used in the preparation of (*a*) normal salts, (*b*) acid salts, and (*c*) basic salts.

5. Write a concise account of the oxides and oxyacids of nitrogen.

6. Compare and contrast the properties of water with those of sulphuretted hydrogen.

No. 12

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. An alchemist once remarked : "The whole art of chemistry is in salt." Discuss the advances made in theoretical chemistry by investigation of the properties of salts.

2. Explain fully the reasons, experimental and theoretical, which we have for believing the molecule of hydrogen to be diatomic.

3. Write a concise account of the chlorides, oxides and oxyacids of phosphorus.

4. How is chemically pure carbon dioxide prepared ? How has the composition by weight of this substance been determined ?

5. Give some account of the reactions which take place when copper is treated with sulphuric acid.

6. State Le Chatelier's principle, and apply it to a consideration of the following reactions—

$N_2O_4 \rightleftharpoons NO_2 + NO_2$
$PCl_5 \rightleftharpoons PCl_3 + Cl_2$
$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$
$2HI \rightleftharpoons H_2 + I_2$.

No. 13

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. The Periodic System groups oxygen and sulphur together. How far is this justified by a resemblance in chemical properties between these elements and their compounds ?

2. From what sources are barium compounds obtained ? Write an account of these compounds and describe also the preparation and properties of metallic barium.

3. For what typical purposes are the following reagents employed in inorganic chemistry : (*a*) caustic soda ; (*b*) sulphuric acid ; (*c*) silver nitrate ; (*d*) potassium dichromate ; (*e*) ammonium hydroxide ; (*f*) ammonium chloride ?

4. Carbon monoxide is said to contain 12 parts by weight of carbon to 16 of oxygen. How would you prove this experimentally ?

5. Describe the preparation and principal properties of the chlorides of phosphorus, arsenic and bismuth.

6. Copper and sodium occur in the same group of the Periodic System. Does this classification find any justification on the grounds of chemical similarity ?

No. 14

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. How is hydrogen obtained (*a*) chemically pure, and (*b*) on the commercial scale ? What are the principal industrial uses of hydrogen ?

2. Write a brief but careful account of the chief oxides and oxyacids of sulphur.

3. Give a careful description of the evidence upon which nitrogen is said to have a valency of 3 or 5.

4. What tests would you employ to distinguish between a pyrophosphate, a metaphosphate and an orthophosphate ? How could you show experimentally that orthophosphoric acid is tribasic ?

5. Describe the action of sulphuric acid upon (*a*) potassium chloride, (*b*) potassium chlorate, (*c*) potassium bromide, (*d*) potassium iodide.

6. Describe the preparation of the chlorides of the following metals, starting in each case from the corresponding oxide : copper, lead, mercury, tin, sodium, aluminium, iron.

No. 15

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Explain the terms *phase, component, degree of freedom, homogeneous equilibrium, heterogeneous equilibrium, apparent equilibrium.*

2. Write an essay on "The Transmutation of the Elements."

3. From what sources are calcium compounds obtained? Write an account of these compounds and describe also the preparation and properties of metallic calcium.

4. Describe the reactions which may occur between sulphuric acid and potassium ferrocyanide.
How is potassium ferrocyanide prepared, and what are its principal properties?

5. Justify, from chemical considerations, the inclusion in a single group of the elements nitrogen, phosphorus, arsenic, antimony and bismuth.

6. Describe a volumetric method for the estimation of copper.

No. 16

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. How far do you think chemistry would be affected if it were shown that atoms have no real existence ?

2. From what sources are zinc compounds obtained ? Write an account of these compounds and describe also the preparation and properties of metallic zinc.

3. A certain solution contains hydrochloric acid, sodium chloride and sulphuric acid. How would you estimate the number of grammes of each substance present in 1 litre of the solution ?

4. Describe the principal tests used for the detection of (*a*) arsenic, (*b*) copper, and (*c*) iron, in qualitative analysis.

5. Describe and explain the action of nitric acid upon metals.

6. By a consideration of three different examples, show the main differences between compounds and mixtures.

No. 17

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe any experiments which have been carried out to ascertain the actual size and weight of atoms.

2. Write a short essay on "Water as a Catalyst."

3. Ozone is said to be an endothermic compound, yet when ozonized oxygen is passed through a heated tube the ozone is almost completely decomposed. How do you account for this ?

4. What is meant by "molecular conductivity" ? How would you measure the molecular conductivity of potassium chloride ?

5. If you were provided with 100 grammes of pure sulphuric acid, how would you proceed to obtain from it as much as possible of each of the elements it contains ?

6. Define and illustrate the term *allotropy*. How has the phenomenon of allotropy been explained ? How would you show that yellow and red phosphorus are allotropic forms of the same element ?

No. 18

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. From what sources are magnesium compounds obtained ? Write an account of these compounds and describe also the preparation and properties of metallic magnesium.

2. You are provided with a sample of brass. How would you prepare from it pure specimens of (*a*) cuprous oxide, (*b*) copper ammonium sulphate, (*c*) zinc chloride, and (*d*) zinc carbonate ?

3. Describe the principal tests used for the detection of (*a*) lead, (*b*) aluminium, and (*c*) nickel, in qualitative analysis.

4. Starting from a test-tube, how would you prepare a pure specimen of silica ? Into which class of oxides would you place silica, and why ?

5. How would you demonstrate (*a*) synthetically and (*b*) analytically, the presence in sulphuric acid of hydrogen, oxygen and sulphur ?

6. Describe the preparation and properties of sulphur chloride, S_2Cl_2.

No. 19

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe the preparation and chief chemical properties of (*a*) chlorosulphonic acid, (*b*) sulphuryl chloride, and (*c*) thionyl chloride.

2. You are provided with a sample of a silver-copper alloy. How would you prepare from it pure specimens of (*a*) cuprous chloride, (*b*) silver chloride, and (*c*) silver ?

3. From what sources are bismuth compounds obtained ? Write an account of these compounds and describe also the preparation and properties of metallic bismuth.

4. Define and illustrate the terms *allotropic*, *monotropic*, and *enantiotropic*, with special reference to the elements sulphur and phosphorus.

5. Describe and explain a colorimetric method of estimating small quantities of ammonia in water.

6. Compare and contrast the properties of iron, cobalt and nickel and their chief compounds.

No. 20

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. How may the hardness of water be accurately determined ? Describe and explain the permutite method of softening water.

2. Explain the reactions which occur (*a*) when sand is warmed with calcium fluoride and concentrated sulphuric acid, and (*b*) when the gas in (*a*) is passed into water.

In what respects does silicon resemble (*a*) carbon, and (*b*) boron ?

3. From what sources are antimony compounds obtained ? Write an account of these compounds and describe also the preparation and properties of metallic antimony.

4. The Periodic System groups carbon, silicon, tin and lead together. How far is this justified by the resemblance in chemical properties between these elements and their compounds ?

5. Describe and explain the methods employed for the desilverization of argentiferous lead.

6. With silver chloride, ammonia forms the compounds $AgCl.NH_3$, $2AgCl.3NH_3$, and $AgCl.3NH_3$. Deduce, from the phase rule, what will happen when ammonia is passed into an evacuated vessel containing silver chloride, the temperature being constant.

No. 21

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe and explain the phase rule diagram for equilibria between any two or three of the following phases of sulphur : rhombic, monoclinic, liquid, vapour.

2. From what sources are chromium compounds obtained ? Write an account of these compounds and describe also the preparation and properties of metallic chromium.

3. Describe carefully how you would estimate the percentage by weight of SiO_2 in ordinary soda-glass.

4. Describe the commercial preparation of hydrogen. What are the principal uses of this substance ? With what elements does hydrogen combine directly, and under what conditions ?

5. If you were provided with some pure mercury, how would you proceed to determine its atomic weight ?

6. Describe and explain the effect of heat upon the following substances : potassium chlorate, ferrous sulphate crystals, mercuric iodide, sodium formate.

No. 22

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What is meant by *conductivity water*? How would you prepare it?

2. Compare and contrast the preparation and properties of the chlorides of copper with those of mercury.

3. How does silicon occur in nature? How may the element be obtained from (*a*) silica, and (*b*) glass?

4. Describe the commercial preparation of (*a*) potassium nitrate and (*b*) potassium chlorate.

5. What are (*a*) Fehling's solution and (*b*) Nessler's solution? How are they made and for what purposes are they used?

6. Starting from barium nitrate, how would you prepare a specimen of barium peroxide? What is the action upon this substance of (*a*) heat and (*b*) dilute acids?

No. 23

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Compare and contrast the properties of carbon and silicon and *five* typical compounds of each.

2. Describe and explain the principal chemical changes which occur in simple photography.

3. How is sodium thiosulphate prepared ? Describe the action of this substance upon (*a*) iodine, (*b*) bromine, and (*c*) silver chloride.

4. How is calcium carbide prepared ? Suggest a method for estimating the purity of a commercial sample of this substance.

5. Describe the preparation and collection of pure chlorine, and state how you would test the purity of your specimen.

6. Describe the preparation of the anhydrous chlorides of aluminium, copper and iron.

No. 24

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What experiments would you make in order to show that the chlorides of copper obey the Law of Multiple Proportions ?

2. Describe the commercial preparation of (*a*) sodium carbonate and (*b*) potassium bromide,

3. Mercurous chloride is sometimes given the formula HgCl, and at others the formula Hg_2Cl_2. How would you try to decide between these two formulae, and what difficulties would you have to overcome ?

4. Given a supply of sodium sulphate, how would you convert it as completely as possible into sulphuric acid ?

5. The action of heat upon lead nitrate is expressed in the following equation

$$2Pb(NO_3)_2 = 2PbO + 4NO_2 + O_2.$$

Suggest a method of verifying this equation experimentally.

6. Given a supply of stibnite, how would you prepare antimony from it ? The antimony obtained from this source usually contains a little arsenic ; how may it be freed from this impurity ?

No. 25

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Discuss the phenomenon of efflorescence in terms of the phase rule. How would you measure the vapour pressure of a crystalline hydrate ?

2. A certain liquid is believed to be a solution of sodium arsenite. How would you ascertain whether this belief was justified ? How may a solution of sodium arsenite be estimated ?

3. According to the Periodic System, there should be chemical similarity between (*a*) tin and lead, (*b*) zinc and mercury. How far is this borne out by the actual properties of these elements and their compounds ?

4. If you were provided with some pure magnesium, how would you proceed to determine its atomic weight ?

5. Starting from cupric oxide, how would you prepare specimens of (*a*) cupric bromide and (*b*) cuprous bromide ?

6. How is nickel carbonyl prepared, and what are its chief uses and properties ? How may its formula be established ?

No. 26

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Explain in terms of the ionic theory—

(i) the fact that the heat of neutralization of strong acids is approximately constant ;

(ii) the fact that a concentrated solution of copper chloride is green but on dilution goes blue ;

(iii) the fact that cobalt chloride crystals are pink but the anhydrous salt blue ;

(iv) the fact that an aqueous solution of sodium carbonate is alkaline to litmus.

2. How would you estimate the hydrogen peroxide and oxalic acid in a solution containing both ?

3. Justify, from chemical considerations, the inclusion of sodium, silver and copper in the same group of the Periodic System.

4. Write an essay on " Natural Waters."

5. Given a supply of copper sulphate, how would you use it to determine the atomic weight of copper ?

6. Describe and explain the action of potassium iodide solution upon (*a*) lead nitrate solution, (*b*) mercuric chloride solution, (*c*) copper sulphate solution, and (*d*) iodine.

No. 27

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State Henry's Law and Dalton's Law relating to the solubility of gases in liquids. A mixture of 50 c.c. of oxygen and 50 c.c. of nitrogen is shaken with a litre of water at 0° C. and 760 mm. pressure until no further solution takes place. Calculate the percentage composition by volume of the resulting gas mixture.

(Solubility of oxygen at 0° C. 760 mm. = 0·04 c.c. per c.c. ; solubility of nitrogen at 0° C. 760 mm. = 0·02 c.c. per c.c.)

2. It is required to determine the purity of a commercial sample of barium chloride. Explain the method you would adopt.

3. Give a brief account of the principal inorganic substances (including gaseous hydrocarbons) obtained by the distillation of coal.

4. What is the action of excess of potassium cyanide upon copper sulphate solution ? What use is made of this action in qualitative analysis ?

5. Write an essay on the chemistry of fertilizers.

6. Given a supply of chromic oxide, how would you prepare a specimen of metallic chromium from it ? What are the principal properties of chromium, and why was the name chromium given to the element ?

No. 28

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State Dalton's Law relating to the solubility of gases in liquids, and describe an experimental method of demonstrating its truth.

A mixture of 120 c.c. of carbon dioxide and 40 c.c. of hydrogen is shaken with a litre of water at 0° C. and 760 mm. pressure until no further solution takes place. Calculate the percentage composition by volume of the resulting gas mixture.

(Solubility of carbon dioxide at 0° C. 760 mm. = 1·8 c.c. per c.c.; solubility of hydrogen at 0° C. 760 mm. = 0·02 c.c. per c.c.)

2. How would you estimate the ferrous and ferric iron in a solution containing both ?

3. Describe the reactions of the common acids with copper.

4. Write the formulae for: carnallite, stibnite, galena, kieserite, Epsom salt, silver glance, horn silver, cerussite, olivine.

5. Hydrogen is sometimes prepared by dissolving iron in dilute sulphuric acid. What impurities would you expect to find in the gas obtained in this way, and how would you remove them ?

6. Describe the commercial preparation of chlorine. What are the principal uses of this substance ? With what elements does chlorine combine directly, and under what conditions ?

No. 29

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State Hess's Law. The heat of combustion of methane is 213,500 calories, while the heats of formation of carbon dioxide and water are respectively 94,300 and 68,300 calories. Calculate the heat of formation of methane.

2. In organic chemistry, substances are often extracted from aqueous solution by means of ether or some other solvent immiscible with water. Show that, for a given volume of such solvent, it is better to extract several times with small portions than to use all the solvent at once.

3. Describe the titanous chloride method of estimating ferric iron.

4. Describe briefly but carefully the commercial preparation and uses of quicklime. What are (*a*) mortar, (*b*) Portland cement, (*c*) hydraulic cement, and (*d*) concrete ? Explain the changes which occur when mortar " sets."

5. Describe the reactions of the common acids with mercury.

6. Compare and contrast the properties of water with those of sulphuretted hydrogen. What views have been expressed on the constitution of liquid water ?

No. 30

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. With what advances in chemical theory do you associate the names of Avogadro and Cannizzaro ?

2. Given ordinary concentrated hydrochloric acid, how would you prepare an accurately decinormal solution of it without employing standard alkali ?

3. Given a specimen of bronze, how would you proceed to prepare from it pure specimens of (*a*) copper and (*b*) tin ?

4. Describe the preparation and collection of pure oxygen, and state how you would test the purity of your specimen.

5. Starting from manganese dioxide, how would you prepare a crystalline specimen of potassium permanganate ? Mention some of the principal uses of this substance.

6. Compare and contrast the action of (*a*) sodium hydroxide and (*b*) ammonium hydroxide upon (i) iodine, (ii) chlorine, (iii) aluminium sulphate solution, (iv) copper sulphate solution.

No. 31

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State and explain van der Waals' equation, and describe the phenomena which led to its formulation.

2. What are the main constituents of coal-gas ? How would you estimate the percentage by volume of each of them in a given specimen of the gas ?

3. Describe and explain a method employed for the volumetric estimation of nitrites.

4. Describe the reactions of the common acids with silver and lead.

5. Give an account of the metallurgy of iron and steel, with particular reference to the chemistry of the processes you describe.

6. It has been asserted that in ozonized oxygen there are traces of a compound (" oxozone ") of the formula O_4. How would you propose to investigate this problem, and what properties would you expect oxozone to possess ?

No. 32

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe a gravimetric method for the estimation of phosphates or P_2O_5.

2. Write short notes on (*a*) passivity of metals, (*b*) " nascent " hydrogen, (*c*) negative catalysts, (*d*) eutectic mixtures.

3. Write an essay on the chemistry of gaseous fuels.

4. Explain the principal uses of sodium thiosulphate in volumetric analysis. How would you proceed to make up an accurately decinormal solution of this substance ?

5. Describe Andrews' work on the behaviour of carbon dioxide under pressure.

6. Explain the terms *heat of solution, heat of neutralization, heat of formation* and *heat of combustion.*

The heat of combustion of acetylene is 310,000 cal., and that of carbon is 94,300 cal. The heat of formation of water is 68,300 cal. Calculate the heat of formation of acetylene.

No. 33

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. "The atomic weight of our elements as ordinarily conceived is not a characteristic number, but rather in many cases an apparently fortuitous average of weights which have real significance."—Sir James Walker.

Discuss this statement and comment upon the facts to which reference is implied.

2. Write an essay upon valency.

3. Describe and explain the principal uses of silver nitrate in volumetric analysis, referring particularly to the estimation of chlorides in acid solution.

4. Describe the preparation, collection and properties of pure ammonia, and state how you would test the purity of your specimen.

5. Describe and explain the changes which occur when concentrated nitric acid reacts with concentrated hydrochloric acid.

6. Hydriodic and sulphurous acids are often described as "unstable" substances. What does this statement mean? How far is it borne out by experimental facts? Do you consider instability and great reactivity to be synonymous from a chemical point of view?

No. 34

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. The heat of formation of benzene is 4000 cal. If the heats of formation of carbon dioxide and water are respectively 94,300 and 68,300 cal., find the heat of combustion of benzene.

2. Describe (*a*) the Bessemer process, and (*b*) the Siemens-Martin process, for the manufacture of steel.

3. State exactly how you would proceed to determine the solubility of iodine in water at room temperature.

4. How is hydroxylamine prepared ? What are its chief properties and uses ? How has its constitution been determined ?

5. You are provided with an alloy of tin, lead and antimony. How would you prepare from it specimens of (*a*) stannic chloride, (*b*) red lead, and (*c*) tartar emetic ?

6. Under what conditions does water react with carbon ? To what industrial use is this reaction put ?

No. 35

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State and explain Guldberg and Waage's Law of Mass Action, and illustrate your answer by reference to the action—

$$CH_3.COOH + C_2H_5.OH \rightleftharpoons CH_3.COOC_2H_5 + H_2O$$

The equilibrium constant of this reaction is 0·25. What would be the composition of the equilibrium mixture if 2 gramme molecules of acetic acid were mixed with 5 gramme molecules of ethyl alcohol ?

2. Explain what is meant by "partition coefficient," and say how you would determine experimentally the partition coefficient of iodine between water and benzene.

3. How would you conduct a complete quantitative analysis of washing soda ?

4. Explain the principal uses of potassium permanganate in volumetric analysis.

5. Describe and explain the action of water upon the following substances : potassium cyanide, phosphorus pentachloride, borax, sodium, aluminium chloride.

6. Write a descriptive account of electrical methods for the extraction of metals on the large scale.

No. 36

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write an essay upon catalysis, referring particularly to any explanations of catalytic action which you may know.

2. How would you conduct a complete quantitative analysis of ferrous ammonium sulphate ?

3. You are given a syphon of soda-water. How would you determine the weight of carbon dioxide it contains ?

4. Describe the miner's safety lamp, and explain the principles upon which its action depends.

5. Describe the preparation of a pure specimen of sulphur dioxide. Upon what experimental evidence is the formula SO_2 given to a molecule of this gas ?

6. Cryoscopic determinations of the molecular weight of ethyl alcohol in benzene gave results varying from 46 to 200. What conclusions do you draw from these figures ? Mention other examples of this and analogous phenomena.

No. 37

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Avogadro's Hypothesis lies "at the root of the entire symbolic system of formulae used by chemists in representing molecular composition and molecular interactions." Demonstrate the truth of this statement.

2. Explain the principal uses of potassium dichromate in volumetric analysis. How would you proceed to make up an accurately decinormal solution of this substance ?

3. Write an account of the use of the spectroscope in chemistry.

4. How is sodium obtained commercially ? What are the principal uses of this metal (*a*) on the large scale and (*b*) in the laboratory ?

5. Briefly indicate how the following formulae have been established : N_2O, SO_2, CH_4, HI, SiF_4.

6. Describe the commercial extraction of iodine. What impurities are likely to be present in the commercial product, and how may they be eliminated ?

No. 38

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Discuss the value of a chemical equation as a means of conveying information.

2. Write a concise account of the rare gases of the atmosphere.

3. Describe the preparation and properties of (*a*) the oxides, and (*b*) the anhydrous chlorides, of iron.

4. Briefly indicate how the following formulae have been established : NH_3, CO, $COCl_2$, CS_2, O_3.

5. Outline and explain the method employed for the separation of the metals lead, mercury (ic), bismuth, copper, cadmium, arsenic, antimony, and tin in qualitative analysis.

6. A specimen of manganese dioxide is suspected to be contaminated with carbon. How would you ascertain whether this is so ? How would you estimate the percentage by weight of pure manganese dioxide in such an impure specimen ?

No. 39

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe and explain the use of the following reagents in qualitative analysis: Yellow ammonium sulphide, sodium carbonate, charcoal, sodium phosphate, barium chloride, silver nitrate.

2. Explain and illustrate *four* of the following terms: dissociation constant, complex ion, exothermic compound, hydrate, eutectic mixture.

3. Briefly indicate how the following formulae have been established: NO_2, NO, H_2S, HCl, PH_3.

4. How would you determine experimentally the heat of formation of carbon monoxide?
State the *Law of Constant Heat Summation.*

5. Given a supply of metallic iron, how would you prepare from it (*a*) ferrous sulphate, (*b*) ferric sulphate, (*c*) ferrous hydroxide, (*d*) ferrous oxide, (*e*) ferric hydroxide.

6. How is aluminium obtained commercially? What are the principal uses of this metal (*a*) on the large scale, and (*b*) in the laboratory?

No. 40

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write an essay upon " The Electronic Theory of Valency."

2. Describe and explain the method employed for the separation of the metals iron, chromium, and aluminium in qualitative analysis.

3. It is required to determine the strength of a commercial sample of hydrogen peroxide solution. Describe a gasometric method which could be employed for this purpose, mentioning all important practical details.

4. Describe the reactions which occur between the following substances, stating the necessary conditions—
(i) phosphorus, bromine, and water.
(ii) chlorine, caustic soda, and water.

5. What experiments would you carry out if you were required to determine the atomic weight of arsenic ?

6. Describe the extraction of zinc from its ores. For what purposes is this metal used (*a*) in industry, and (*b*) in the laboratory ?

No. 41

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. "La Chimie est une science française." Discuss.

2. Describe the preparation and properties of an oxide and an oxyacid of boron. Upon what evidence is boron considered to be tervalent ?

3. Explain, in terms of the ionic theory, the use of potassium chromate as indicator in the volumetric determination of chlorides in neutral solution by means of standard silver nitrate solution.

4. Starting from caustic soda, how would you prepare specimens of (*a*) sodium sulphite, (*b*) sodium bisulphite, (*c*) sodium thiosulphate, and (*d*) sodium nitrite ?
Describe the action of acids upon these substances.

5. Describe attempts which have been made to isolate *ammonium*. What is the effect of heat upon ammonium sulphate, ammonium chloride, ammonium nitrite, ammonium nitrate, ammonium carbonate and ammonium dichromate ?

6. The following figures represent the percentage weight analysis of five different compounds : (i) H = 2·74, Cl = 97·26 ; (ii) H = 11·11, O = 88·89 ; (iii) H = 5·88, O = 94·12 ; (iv) Cl = 81·61, O = 18·39 ; (v) Cl = 52·59, O = 47·41.
State the Laws of Chemical Composition which these figures illustrate, and show how the laws may be deduced from Dalton's Atomic Theory.

No. 42

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Discuss the position of silicon in the periodic system.

2. Describe the preparation and principal properties of the oxyacids of chlorine. How far do bromine and iodine form analogous compounds ?

3. Describe carefully a volumetric method of estimating the percentage by weight of iron in an ordinary pen-nib.

4. From consideration of mass action and electrolytic dissociation, prove the relationship

$$\frac{m^2}{(1-m)V} = K$$

(Ostwald's Dilution Law, where m = degree of ionization, V = dilution, K = constant.)

5. How would you determine the percentage composition of the following mixtures : (*a*) potassium chloride and potassium chlorate ; (*b*) potassium chloride and sodium chloride ; (*c*) ammonium chloride and ammonium nitrate ?

6. Translate and comment upon : L'air est un mélange ; on le forme en mêlant 4 volumes d'azote à un volume d'oxygène et il n'y a aucun dégagement de chaleur, comme il arriverait s'il y avait combinaison ; en second lieu, les proportions des deux gaz ne sont pas dans un rapport simple ; enfin quand l'air se dissout, c'est chacun de ces deux gaz avec son propre pouvoir de solubilité qui se dissout dans l'eau ; et l'air dissous n'a plus la même constitution que l'air ordinaire ; il renferme en effet 32 pour 100 d'oxygène.

L'air, au point de vue chimique, a les propriétés de l'oxygène tempérées par la présence de l'azote ; il sert à la respiration des animaux et des plantes ; il produit l'oxydation des métaux.

No. 43

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Discuss the position of hydrogen in the periodic system.

2. Describe, with full practical detail, the ebullioscopic (elevation of the boiling-point) method of molecular weight determination.

3. State the main differences between chemical compounds and mechanical mixtures. Into which class would you put a saturated solution of common salt, and why ?

4. Describe, with full practical detail, how you would estimate volumetrically the strength of a solution of borax.

5. Give a short account of the metallurgy of zinc. To what elements do you consider zinc to be most closely related chemically ? Give your reasons in full.

6. You are provided with a specimen of dolomite. How would you prepare specimens of (*a*) magnesium sulphate and (*b*) calcium carbonate from it ?

No. 44

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe and explain the action of nitric acid upon metals.

2. Write a systematic account of double salts, with special reference to (*a*) their classification, (*b*) the question of their existence in solution, and (*c*) the distinction between them and complex salts. Illustrate your answer by definite examples.

3. Explain the term *molecular conductivity* and describe a method by which the molecular conductivity of a substance can be determined. How may molecular conductivity be employed in calculating the degree of ionization of a dissolved electrolyte ?

4. It was at one time believed that the atomic weight of carbon is 6. Explain fully the experimental evidence and theoretical reasoning which lead us to conclude that the atomic weight of carbon is not 6 but 12.

5. How are chlorides estimated volumetrically (*a*) in neutral solution and (*b*) in acid solution ?

6. Describe carefully how, starting from yellow phosphorus, you would prepare a pure specimen of phosphonium iodide. Compare and contrast the properties of this substance with those of ammonium iodide.

No. 45

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State Henry's Law. Describe and explain the deviation of certain gases from this law.

2. Define the term *chemical equilibrium*. Illustrate your answer by references (i) to systems in (*a*) stable equilibrium and in (*b*) unstable equilibrium, and (ii) to metastable systems.

3. Describe, with full practical detail, how you would measure the rate of esterification of alcohol by acetic acid.

4. Discuss the relation between the atomic weight and vapour density of each of the following elements : mercury, sulphur, phosphorus, iodine, argon.

5. Upon what evidence is the formula SO_3 assigned to a molecule of sulphur trioxide ?

6. Describe the principal compounds of barium. How would you convert barium sulphate into barium chloride ?

No. 46

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. How would you estimate the tin in a tin ore such as cassiterite ?

2. Define the terms *deliquescence*, *efflorescence*, *hydrate*, and *water of crystallization*. How far is it correct to describe a hydrate as a " molecular compound " ?

3. It is sometimes stated that when caustic soda acts upon a non-metal the latter is simultaneously oxidized and reduced. Discuss this statement, and give examples.

4. You are required to prepare a pure specimen of nitrogen peroxide from the oxygen and nitrogen of the atmosphere. How would you proceed ?

5. Upon what evidence do we consider that the molecule of argon is monatomic ?

6. Discuss the efficacy and convenience of the various methods employed to dry gases.

No. 47

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. "A theory of valency can only be justified by showing that it is applicable to chemistry as a whole." Discuss and illustrate.

2. How would you compare experimentally the relative strengths of bases ?

3. Describe a spectroscope and mention the uses to which it is put in chemistry.

4. Outline and explain the method employed for the separation of the metals zinc, manganese, cobalt and nickel in qualitative analysis.

5. Mention the principal naturally-occurring compounds of phosphorus, and describe the extraction of the element from any one of them.

6. Describe the reactions which occur between the following substances, stating the necessary conditions—

(i) carbon dioxide, water, ammonia, common salt ;

(ii) alcohol and sulphuric acid.

No. 48

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Explain in outline how X-rays may be used to elucidate the structure of crystals.

2. Describe, and explain the method of use, of an apparatus to show the migration of ions. Discuss Kohlrausch's work on the migration of ions. What is meant by the *transport number* of an ion ?

3. What methods are available for the determination of the basicity of acids ? How would you proceed to demonstrate experimentally the basicity of ortho-phosphoric acid ?

4. Give an account of the extraction of copper from its ores, with particular reference to the chemistry of the processes you describe.

5. Describe the action of sulphuric acid upon (*a*) oxalic acid, (*b*) formic acid, (*c*) sugar, (*d*) zinc, (*e*) copper.

6. Describe the preparation and collection of hydrobromic acid gas and mention the principal properties of this substance.

No. 49

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What do you know of Bohr's theory of the structure of the atom ?

2. How may the strengths of various acids be compared ? Mention four methods in outline and describe one in detail.

3. Outline the method employed for the separation of the metals silver, lead, and mercury (ous) in qualitative analysis.

4. Describe and explain the use of the following reagents in qualitative analysis : sulphuretted hydrogen, ammonium hydroxide, ammonium chloride, hydrochloric acid, borax.

5. Explain fully how you would prepare and standardize a solution of sodium thiosulphate. For what purposes is such a solution employed ?

6. How is calcium hydride prepared ? What are its chief properties and for what purposes is it used ? How would you estimate the percentage by weight of hydrogen in it ? What other metallic hydrides do you know ?

No. 50

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What do you understand by the valency of an element ? How far is it true to say that the valency of an element is the number of units into which its combining power can be divided ?

2. Discuss the relative merits of the oxygen standard and the hydrogen standard of atomic weights. How far does recent work upon the structure of the atom affect the problem ?

3. Given a standard solution of sodium thiosulphate, suggest a method of finding the strength of an unknown solution of potassium dichromate. Give practical details.

4. What do you know of the history of the halogens ? How was chlorine shown to be an element ?

5. Describe, with full practical detail, how you would prepare pure specimens of (*a*) mercury from cinnabar, (*b*) ferrous sulphate from iron pyrites, (*c*) silver from horn silver, and (*d*) tin from cassiterite.

6. If you were provided with some lead acetate, how would you prepare a specimen of lead dioxide ? How does this substance react with (*a*) acids and (*b*) sulphur dioxide ?

No. 51

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. "A crystal of common salt is an orderly arrangement of sodium and chlorine ions." Discuss and explain.

2. What is meant by the *strength* of an acid ? Describe the way in which the strength of acids may be compared (*a*) by the inversion of cane sugar and (*b*) by the hydrolysis of methyl acetate.

3. How would you prepare an accurately decinormal solution of iodine ? For what purposes is such a solution employed ?

4. Describe the reactions which occur between the following substances, stating the necessary conditions—

(i) ammonia, copper sulphate, water ;

(ii) ammonia, chlorine, water.

5. Write a short account of (*a*) the rusting of iron and (*b*) the passivity of iron.

6. Give some account of the evidence upon which the following formulae are based—

$KMnO_4$, potassium permanganate ;

$K_2Cr_2O_7$, potassium dichromate ;

$Na_2SO_4.10H_2O$, sodium sulphate decahydrate ;

$NaNH_4HPO_4$, microcosmic salt.

No. 52

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. In the early days of the atomic theory it was suggested that equal volumes of gaseous elements under similar conditions of temperature and pressure contain equal numbers of atoms. How did this hypothesis fail, and how was it modified to fit experimental facts ?

2. State and explain the Law of Mass Action, and illustrate it by reference to (*a*) the action of water on bismuth chloride, and (*b*) the reaction between ferric chloride and ammonium thiocyanate.

3. Describe the preparation and collection of hydriodic acid gas and mention the principal properties of this substance.

4. Describe carefully any accurate methods of determining the composition of water (*a*) volumetrically, and (*b*) gravimetrically.

5. What impurities are likely to be present in cast-iron ? How would you test for their presence ? How may they be removed ?

6. You are provided with a solution containing a known weight per litre of a monacid base. How would you determine the molecular weight of the base ?

No. 53

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Briefly describe the principal contributions to chemistry of Sir William Ramsay.

2. "Colloid chemistry is the chemistry of bubbles, drops, grains, filaments and films." Discuss this statement, and write an account of the principal characteristics of colloidal solutions.

3. Describe Victor Meyer's method of vapour density determination, mentioning particularly the practical details necessary to ensure a successful result.

4. Suggest a volumetric method of estimating the percentage by weight of copper in copper sulphate crystals, pointing out any practical details which must be observed in order to get a satisfactory result.

5. Explain fully the reasons for assigning the formula NH_3 to a molecule of ammonia, and point out how far the argument rests on theoretical assumptions and how far upon experimental data.

6. Describe the preparation and properties of the oxides, chlorides, and sulphates of cobalt and nickel.

No. 54

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What method would you use to determine experimentally the solubility of ammonia in water at room temperature and pressure ?

2. Give a short outline of the development of the atomic and molecular theory.

3. State the Phase Rule and illustrate its application by reference to any two examples.

4. Give an account of the desilverization of argentiferous lead.

5. Explain fully the reasons for assigning the formula H_2O to a molecule of water, and point out the theoretical assumptions involved in your argument.

6. Describe, with full practical detail, how you would show that one volume of hydrogen combines with one volume of chlorine to form two volumes of hydrochloric acid gas. What light does this result throw upon the constitution of the molecules of these gases ?

No. 55

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write a critical essay on " Chemical Nomenclature."

2. Define the following terms, and illustrate your answer by examples : dissociation, allotropy, transition point, solubility product, hydrolysis.

3. Describe Hofmann's method of vapour density determination, and state in what circumstances you would employ it.

4. Describe, with full practical detail, how you would estimate volumetrically the strength of a given solution of hydrogen sulphide.

5. Mention the principal chemical and physical properties which distinguish metals from non-metals, illustrating your answer by reference to sodium, mercury, hydrogen, arsenic and oxygen.

6. What tests would you employ to distinguish between (*a*) a phosphate and an arsenate, (*b*) a sulphite and a thiosulphate, and (*c*) a chloride and a bromide ?

No. 56

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write a short essay on the part played by oxygen in the development of chemical theory.

2. Discuss in terms of the phase rule the reversible reactions :
(i) $CaCO_3 \rightleftharpoons CaO + CO_2$.
(ii) $2HI \rightleftharpoons H_2 + I_2 \rightleftharpoons H_2 + I + I$.
(iii) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$.

3. What is meant by a chemically pure substance ? What methods are employed to ascertain whether a substance is pure or not ?

4. Outline and explain the method employed for the separation of the metals calcium, barium and strontium in qualitative analysis.

5. What do you know of the history of (*a*) iron, (*b*) cobalt, and (*c*) nickel ?

6. Describe and explain the changes which occur when aqueous solutions of the following substances are electrolysed, mentioning particularly the effect upon the products of reaction caused by the material of the electrodes : hydrochloric acid, sodium sulphate, potassium hydrogen sulphate, lead nitrate, copper sulphate, potassium chloride.

No. 57

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Briefly describe the principal contributions to chemistry of Arrhenius.

2. Exactly what is meant by the *velocity of a chemical reaction*? Discuss the principal conditions which affect the velocity of a chemical reaction, with special reference to any three examples.

3. Define the terms *hydration* and *hydrolysis* and illustrate your answer by giving four examples of each phenomenon.

4. Write a concise comparative account of the halogens.

5. What method would you use to determine experimentally the solubility of carbon dioxide in water at room temperature and pressure?

6. How would you prepare a pure aqueous solution of hydrogen peroxide? How does hydrogen peroxide react with (*a*) potassium iodide, (*b*) potassium dichromate, (*c*) lead sulphide, (*d*) silver oxide?

No. 58

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What general methods are available for the preparation of the halogen hydracids ?

2. Describe, with full practical detail, how you would estimate volumetrically the strength of a given solution of ammonia.

3. Describe the effect of heat upon the following substances, and mention the principal properties of any gaseous products of the reactions you describe : (*a*) sodium bicarbonate, (*b*) ferrous oxalate, (*c*) mercuric iodide.

4. Suggest an experimental method of determining the atomic weight of silver.

5. Write a systematic account of the reactions of (*a*) metallic, and (*b*) non-metallic, chlorides with water.

6. Give some account of the evidence upon which the following formulae are based—

$NaNO_2$, sodium nitrite ;
Na_2O_2, sodium peroxide ;
$POCl_3$, phosphorus oxychloride ;
HNO_3, nitric acid.

No. 59

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State the Law of Gaseous Volumes and describe an experimental method of demonstrating its truth.

2. How are the solubilities of sparingly soluble substances, such as silver chloride, accurately determined ?

3. What method would you use to determine experimentally the solubility of oxygen in water at room temperature and pressure ?

4. Briefly discuss the position of manganese in the Periodic System. With what elements do you consider manganese shows the closest analogies ? Give reasons for your answer.

5. Suggest experimental methods for the determination of the atomic weight of iron.

6. Describe the effect of heat upon the following substances, and mention the principal properties of any gaseous products of the reactions you describe : (*a*) mercuric cyanide, (*b*) lead nitrate, (*c*) ammonium nitrate, (*d*) ammonium dichromate.

No. 60

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Briefly describe the principal contributions to chemistry of (*a*) Priestley, (*b*) Cavendish, and (*c*) Lavoisier.

2. Explain and illustrate the terms sol, gel, dispersoid, suspensoid, emulsoid, dispersion medium, disperse phase.

3. Describe exactly the method you would employ to determine the solubility of oxalic acid crystals in water at (*a*) room temperature and (*b*) 100° C.

4. Describe *two* methods of estimating the "available chlorine" in bleaching-powder.

5. Mention the chief ores of nickel, and describe briefly the Mond process for the extraction of the metal.

6. Calcium phosphate is insoluble in water but soluble in dilute hydrochloric acid. Explain this in terms of the Ionic Theory.

No. 61

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Give a concise account of the work which led to the overthrow of the Theory of Phlogiston.

2. State the Law of Multiple Proportions and describe an experimental method of demonstrating its truth.

3. State exactly how you would proceed to calibrate a burette as accurately as possible.

4. Describe the preparation and properties of the oxides of manganese. How would you estimate the manganese dioxide in a specimen of pyrolusite ?

5. How would you determine the equivalent of (*a*) cobalt and (*b*) nickel ?

6. It is believed that when ammonia is dissolved in water the following equilibria are set up—

$$NH_3 + H_2O \rightleftharpoons NH_4OH \rightleftharpoons NH_4^{\cdot} + OH'$$

Describe the experimental evidence upon which this belief rests.

No. 62

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe methods by which the atomic weights of the chief elements present in the atmosphere could be determined.

2. Starting from potassium dichromate, how would you prepare specimens of potassium chromate, chromium trioxide, chromous chloride, chrome alum, chromium sulphate ?

3. Describe and explain the use of the following substances as reducing agents : stannous chloride, hydrogen iodide, carbon, " nascent " hydrogen, zinc dust.

4. What is meant by " Brownian movement " ? How would you demonstrate it experimentally ? What deductions may be made from this phenomenon ?

5. State exactly how you would proceed to determine the solubility of sodium carbonate in water at (*a*) room temperature and (*b*) 80° C.

6. Write an account, illustrated by examples, of the use of (*a*) electrolysis, (*b*) the electric spark, and (*c*) the silent electric discharge, in the investigation and preparation of chemical substances.

No. 63

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe the cyanamide process for the fixation of nitrogen.

2. Describe the commercial preparation of chlorine, and mention the principal uses of this gas.

3. Explain the methods used to determine the composition of gas mixtures, with particular reference to the manipulation of any apparatus you describe.

4. Write an essay on " Flame and Combustion."

5. Given a supply of metallic iron, how would you prepare a pure specimen of ferrous ammonium sulphate ? Explain the use of this substance in volumetric analysis.

6. What is meant by a colloidal solution ? How would you prepare colloidal solutions of (*a*) platinum and (*b*) silicic acid ?

No. 64

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Give some account of the importance of catalysis in industrial chemistry.

2. Nernst described Avogadro's Hypothesis as "an inexhaustible horn of plenty." Show, by a consideration of the importance to chemistry of this hypothesis, that the description is justified.

3. Describe carefully the method you would adopt to prepare as pure as possible a specimen of hydrogen, starting from ordinary tap-water.

4. Give a clear account of some classical researches upon the atomic weight of silver.

5. Starting from metallic copper, how would you prepare specimens of cupric oxide, cupric nitrate, cupric sulphate, cuprammonium sulphate, copper ammonium sulphate ?

6. If you were given an unknown element, how would you proceed to ascertain experimentally whether it should be classed as a metal, non-metal or metalloid ?

No. 65

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Briefly sum up the main points of the Kinetic Theory of Gases. Show how this theory affords an explanation of Boyle's Law, Graham's Law and Avogadro's Hypothesis.

2. Given a definite weight of potassium chlorate, how would you prepare from it as much chlorine, oxygen, and potassium sulphate as possible ?

3. Describe the ammonia-soda process for the manufacture of sodium carbonate.

4. What general methods may be employed to prepare acids ? Give examples, and state how you would prepare (*a*) sulphuric acid from sodium sulphate, (*b*) ortho-phosphoric acid from phosphorus, and (*c*) hydriodic acid from potassium iodide.

5. State the *Law of Diffusion of Gases.* How are the rates of diffusion of two gases compared experimentally ? What is the ratio of the rate of diffusion of helium (M.W. = 4) to that of air (vapour density 14·4) ?

6. If you were provided with some pure sulphur, how would you proceed to determine its atomic weight ?

No. 66

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write an essay on "Chemical Reactions which are Influenced by Light."

2. What is meant by "transition point"? How would you determine the transition point in the change rhombic sulphur $\rightleftharpoons$ monoclinic sulphur?

3. Discuss the statement that the last 20 years have witnessed the third crisis in the development of chemical theory.

4. Describe the preparation and properties of the oxides and chlorides of antimony and bismuth. How do these substances react with water?

5. What methods would you employ to determine the molecular weights of (*a*) phosphorus, (*b*) nitrogen peroxide, and (*c*) hydrogen peroxide?

6. Mention some of the principal properties of potassium dichromate, and describe its uses as (*a*) an oxidizing agent, and (*b*) a volumetric reagent. How would you determine its equivalent?

No. 67

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Give a systematic account of methods employed in determining the atomic weights of metallic elements.

2. Given a definite weight of stannic chloride, $SnCl_4$, how would you obtain from it as much as possible of each of the two elements it contains ?

3. What general methods may be employed to prepare salts ? Give examples, and state how you would prepare (*a*) bismuth oxychloride from bismuth, (*b*) potassium hydrogen carbonate from caustic potash, and (*c*) lead iodide from lead.

4. Describe the principal industrial processes for the preparation of caustic soda. For what purposes is this substance employed ?

5. Describe the preparation and properties of the chlorate, bromate, and iodate of potassium. How may potassium chlorate be converted into potassium iodate ?

6. Give a concise account of the chlorides of mercury, phosphorus and copper. Given the higher chloride of each of these elements, how would you prepare specimens of the lower chlorides ?

No. 68

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What methods have been adopted to determine the combining ratio by weight of hydrogen and oxygen ? Give a brief description of *any one* of them, and explain the importance of knowing this ratio as accurately as possible.

2. Compare and contrast the properties of nitrous acid with those of sulphurous acid.

3. Describe the preparation and properties of the hydrides of the elements of the nitrogen family.

4. Describe the preparation and properties of the oxides and chlorides of mercury. What peculiarity of vapour density is shown by mercurous chloride, and how is the peculiarity explained ?

5. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) zinc, (*b*) cobalt, (*c*) magnesium.

6. Define the terms *theory* and *hypothesis*, and illustrate your answer by reference to particular chemical theories and hypotheses.

No. 69

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What do you understand by a *Law of Nature* ? Illustrate your answer by reference to the laws of (*a*) Constant Composition, (*b*) Dulong and Petit, (*c*) Boyle, (*d*) Multiple Proportions.

2. Describe, with full practical detail, how you would estimate volumetrically the strength of a given solution of carbon dioxide.

3. State exactly how you would proceed to calibrate a pipette and graduated flask as accurately as possible.

4. Write a short account of the use of contact agents as catalysts.

5. What is " white lead " ? How is it prepared, and what are its chief uses ?

6. Show, by a consideration of the chief properties of the elements and their compounds, that nitrogen, phosphorus, arsenic, antimony and bismuth are justifiably classed together by chemists.

No. 70

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Explain and illustrate the term *adsorption*. "Typical colloids have a high power of adsorption." Discuss and give examples.

2. Describe Knop's method (i.e. the diphenylamine internal indicator method) for the estimation of ferrous iron.

3. What experiments have been carried out with a view to testing the limits of accuracy of the Law of the Conservation of Matter? Discuss the probable effects upon chemistry if this law was found not to be of universal application.

4. Describe the preparation and properties of (*a*) lead chloride, $PbCl_2$, (*b*) stannous chloride, and (*c*) stannic chloride. What is the action of water upon those substances?

5. Give a systematic account of the reactions between non-metallic oxides and water.

6. Write an account of methods commonly employed to prepare hydrides, with special reference to the hydrides of iodine, sulphur, phosphorus and arsenic.

No. 71

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State the Law of Reciprocal Proportions and describe an experimental method of demonstrating its truth.

2. Explain clearly why the atomic weight of an element is numerically equal to the product of its equivalent and valency. How would you determine experimentally the equivalent of sodium bromide ?

3. State exactly how you would proceed to test the accuracy of an ordinary chemical balance weighing to one-fifth of a milligram.

4. Describe, with all essential practical detail, how you would determine the solubility of potassium nitrate in water at various temperatures.

5. Give a descriptive account of methods commonly used to prepare (*a*) metallic chlorides and (*b*) non-metallic chlorides.

6. If you were provided with some ordinary sand, how would you use it in order to conduct a determination of the atomic weight of silicon ?

No. 72

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe the main features of the phlogiston theory of combustion, pointing out both its merits and its defects. It has been stated that, in the days before Lavoisier, this theory was " scientifically true." Discuss this point of view.

2. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) cadmium, (*b*) tin and (*c*) sodium.

3. Discuss the relative merits of the hydrogen standard and oxygen standard of atomic weights.

4. Describe and explain the actions which take place when the following metals are exposed to damp air : iron, lead, copper, sodium. Discuss the relative merits of tin and zinc as coatings for iron to prevent rusting.

5. What method would you adopt to determine the percentage composition by volume of a mixture of oxygen and nitrous oxide ?

6. Write an essay upon basic and acidic oxides, with special reference to the oxides of nitrogen, phosphorus, arsenic, antimony and bismuth.

No. 73

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Briefly describe the principal contributions to chemistry of van't Hoff.

2. Write a short account of the main features of the Ionic Theory. Explain the following observation: addition of concentrated solutions of either sodium acetate or silver nitrate to a saturated solution of silver acetate causes precipitation of the latter salt.

3. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) lead, and (*b*) silver.

4. How would you prepare a specimen of aluminium oxide from potash alum ? Discuss the properties of this oxide with particular reference to its acidic or basic character.

5. Describe the Haber process for the synthetic production of ammonia.

6. What method would you adopt to determine the percentage composition by volume of a mixture of carbon monoxide, carbon dioxide and methane ?

No. 74

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Mention the main points of the Atomic Theory as formulated by Dalton, and show that some of the chief chemical laws are logical corollaries of the theory.

2. When concentrated hydrochloric acid is added to a saturated solution of common salt, salt is precipitated. Explain this in terms of the Ionic Theory.

3. Starting from aluminium, how would you prepare a specimen of potash alum ? What is the general formula for the alums as a class, and what other members do you know ?

4. Mention some of the principal properties of potassium permanganate, and describe its uses as (*a*) an oxidizing agent, and (*b*) a volumetric reagent.

5. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) bismuth, (*b*) arsenic, and (*c*) antimony.

6. Describe, with full practical detail, how you would estimate volumetrically the strength of a given solution of sulphur dioxide.

No. 75

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Explain and comment on the following statement: The properties of the elements are a periodic function of their atomic numbers.

2. Describe Dumas' method of vapour density determination, mentioning particularly the precautions which must be taken to ensure a satisfactory result.

3. Describe the preparation of phosphine, and compare and contrast its properties with those of ammonia.

4. How are (*a*) potassium cyanide, (*b*) potassium ferrocyanide, (*c*) potassium ferricyanide, and (*d*) potassium thiocyanate, prepared ? Why does a solution of potassium cyanide react alkaline to litmus ?

5. Describe the preparation and properties of the anhydrous chlorides of iron and aluminium. What is the action of water upon these substances ?

6. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) copper, and (*b*) mercury (*ous* and *ic*).

No. 76

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. An aqueous solution of hydrogen chloride dissolves marble readily, while a solution in toluene has no effect. How do you explain this ? Mention any similar phenomena with which you are acquainted.

2. State what is meant by a " buffer salt," and explain the use of such substances in the calibration of an indicator to show P_H values.

3. Describe the Birkeland-Eyde process for the fixation of nitrogen.

4. What method would you adopt to determine the percentage composition by volume of a mixture of nitrogen, nitric oxide and ammonia ?

5. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) iron, (*b*) chromium, and (*c*) aluminium.

6. Give a systematic account of methods employed in determining the atomic weights of non-metallic elements.

No. 77

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe the experimental evidence which leads us to believe in the real existence of atoms and molecules.

2. Define "partition coefficient," and show how the distribution of a solute between two immiscible solvents may be used to investigate molecular complexity.

3. Describe the preparation and properties of ozone and mention any commercial applications of this gas. How has the formula for ozone been established ?

4. Write a comparative survey of the reactions between water and metals.

5. Describe the preparation and properties of the oxides and chlorides of copper.

6. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) manganese, (*b*) barium, (*c*) nickel.

No. 78

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write a short essay on the development of the idea of valency.

2. Discuss concisely the evidence for and against the theory of electrolytic dissociation.

3. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) chlorates, (*b*) arsenates, (*c*) sulphites.

4. What is the principal ore of mercury ? Describe the extraction and purification of the metal, and mention some of its chief chemical properties.

5. What tests would you employ to detect ozone ? Describe experiments to show that this gas is an oxidizing agent.

6. Describe the preparation of the three sodium salts of ortho-phosphoric acid, starting from the acid itself. What are the chief properties of these salts, and how do they react with indicators ?

No. 79

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe some of the ways in which the physical properties of a solution are related to its osmotic pressure, and point out any practical importance of this relationship.

2. What are the principal methods of preparation of (*a*) normal salts, (*b*) acid salts, (*c*) basic salts, (*d*) double salts ?

Which formula do you think more appropriate for bismuth oxychloride, BiOCl or $BiCl_3.Bi_2O_3$? Give your reasons in full.

3. You are given a supply of metallic copper and are required to prepare specimens of (*a*) copper ammonium sulphate, (*b*) cuprammonium sulphate, and (*c*) cuprous chloride. How would you proceed ?

4. How is hydroxylamine prepared ? What are its principal properties, and for what purposes is it used ?

5. Write an account of the preparation, properties, and constitution of silico-chloroform, silicon tetrachloride, silicon tetrafluoride and ortho-silicic acid.

6. Translate and comment upon : Die Formel dieser Verbindung (Stickstoffperoxyd) ist gemäss dem Gesagten NO_2 oder ein Vielfaches davon. Versucht man, hierüber Aufschluss aus der Dampfdichte zu gewinnen, so ergeben sich Werte für das Molargewicht, die mit Druck und Temperatur wechseln. Je niedriger die Temperatur und je höher der Druck ist, um so mehr nähert sich das Molargewicht dem Wert 92, während umgekehrt bei Erhöhung der Temperatur und Verminderung des Drucks sich die Zahlen dem Werte 46 nähern. Bei 100° wird der Wert 46 schon unter 2·3 cm. Druck erreicht und bleibt dann bei weiterer Verminderung des Drucks konstant.

No. 80

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. "Chemical research should be subsidized by the State." Discuss.

2. Accurately define the term *isomorphous*. State Mitscherlich's Law, and show how it may be used in the establishment of atomic weights.

3. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) nitrates, (*b*) phosphates, (*c*) borates.

4. Give a concise description of the way in which oxides are classified, illustrating your answer by reference to particular examples.

5. Write a critical account of the main chemical principles involved in the extraction of metals from their ores.

6. How is lead peroxide prepared, and what are its chief properties? Describe the chemistry of a lead accumulator.

No. 81

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State the Law of Constant Composition, and describe an experimental method of demonstrating its truth.

2. Describe and explain the use made in chemistry of the specific heats of (*a*) metals and (*b*) gases.

3. Describe and explain the tests used in qualitative analysis to detect and confirm the presence of (*a*) bicarbonates, (*b*) oxalates, (*c*) iodides, and (*d*) thiosulphates.

4. Define and illustrate the terms *oxidation* and *reduction*. How would you compare the oxidizing powers of two oxidizing agents ?

5. Mention the chief ores of copper and state how the metal is extracted from them. What alloys of copper are in general use, and for what purposes ?

6. What is the action of concentrated nitric acid upon (*a*) hydrogen chloride and (*b*) hydrogen bromide ? Describe experiments in support of your answer.

No. 82

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Discuss, in terms of the Ionic Theory, the behaviour of litmus, methyl orange and phenol-phthalein when used as indicators.

2. How is potassium dichromate manufactured ? How would you obtain from it (*a*) chromyl chloride, (*b*) potassium chlorochromate, and (*c*) sodium dichromate ?

3. Define and illustrate the terms *oxidizing agent* and *reducing agent*. What tests would you apply to discover whether a given substance was (*a*) an oxidizing agent, or (*b*) a reducing agent ?

4. Describe the preparation and properties of the oxides of lead. Suggest a method of estimating the lead peroxide in a mixture of red lead, lead peroxide, and litharge.

5. Describe in detail a gravimetric method for determining the composition of copper sulphate crystals. How is this substance obtained commercially, and what are its principal uses ?

6. Describe the main principles of the various methods used for the liquefaction of gases, and explain the terms *critical pressure* and *critical temperature*.

No. 83

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. State *Graham's Law*. A certain gas diffuses 1·44 times as quickly as oxygen ; find the molecular weight of the gas.

2. " The molecular weight of a substance is twice its vapour density." Define *molecular weight* and *vapour density*, and state the grounds for believing in the above relation between them.

3. Write a systematic account of the phenomenon of catalysis, illustrating your answer by reference to examples of different types.

4. Briefly describe the principal contributions to chemistry made by Berzelius.

5. Write a concise account of the chemistry of simple photography.

6. The pre-war silver coinage consisted of an alloy of silver and copper. Suggest a method for obtaining a pure specimen of each metal from such an alloy, and also of estimating the percentage composition by weight of the alloy.

No. 84

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write a critical account of the phenomena of hygroscopy, efflorescence and deliquescence, illustrating your answer by reference to typical examples.

2. Briefly describe the principal contributions to chemistry made by Sir Humphry Davy.

3. Write a short essay upon "The Liquefaction of Gases."

4. Given a definite weight of ammonium nitrate, how would you obtain from it as much as possible of each of the elements it contains ?

5. What general methods may be employed to prepare bases ? Give examples, and state how you would prepare (*a*) caustic soda from sodium sulphate, (*b*) litharge from lead peroxide, and (*c*) calcium oxide from calcium sulphate.

6. How is oxygen prepared (*a*) in a state of purity, (*b*) for ordinary purposes in the laboratory, and (*c*) on a commercial scale ? What does the word *oxygen* mean ? Discuss its suitability as a name for the particular gas to which it is applied.

No. 85

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write an essay on electrical methods in chemistry.

2. Give some account of isomorphism. 2·400 grammes of a metal yield 2·907 grammes of its oxide. The metallic sulphate forms an alum with ammonium sulphate. Find the atomic weight of the metal.

3. What experiments would you make to decide whether a given acid was a strong acid or a weak one ?

How would you compare its strength with that of sulphuric acid ?

4. Given a supply of sodium carbonate and bicarbonate, what experiments would you make with these substances to illustrate the truth of the Law of Multiple Proportions ?

5. Describe, with all essential practical detail, three different methods of determining the basicities of acids.

6. Translate and comment upon : Jod und Wasserstoff verbinden sich zu Jodwasserstoffsäure, welche bei gewöhnlicher Temperatur ein farbloses Gas, gleich den anderen Halogenwasserstoffsäuren ist, das der Formel HJ gemäss die Dichte 128 hat. Die Verflüssigung des Jodwasserstoffs unter Atmosphärendruck erfolgt indessen schon bei —34°.

Die Verbindung der beiden Elemente ist noch weniger beständig, als beim Bromwasserstoff. Vermischt man Wasserstoff und Joddampf zu gleichen Raumteilen und erhitzt das Gemenge, so verbindet sich nur ein Teil der Elemente zu Jodwasserstoff, ein anderer bleibt unverbunden. Dies Verhältnis ändert sich auch nicht, wenn man Platinschwamm hinzufügt ; es wird nur der Zustand des Gleichgewichts viel schneller erreicht. Dieser ist mit der Temperatur etwas veränderlich ; bei 520° verbinden sich 76% des Gemenges.

No. 86

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Give some account of chemical discoveries made by means of the spectroscope.

2. Explain and illustrate the term *osmotic pressure*. How is the osmotic pressure of a solution determined directly ?

3. From what sources are tin compounds obtained ? Write an account of these compounds and describe also the preparation and properties of metallic tin.

4. State exactly how you would proceed to find the amount of sulphur dioxide which dissolves when a current of the gas is passed through water.

5. If you were provided with some pure amorphous carbon, how would you proceed to determine its atomic weight ?

6. Define the terms solubility, saturated solution, supersaturated solution.

What peculiarity is shown by the solubility curve of sodium sulphate ? How do you interpret this curve ?

No. 87

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe the phenomenon of *passivity* and comment on the explanations which have been suggested to account for it.

2. From what sources are cadmium compounds obtained ? Write an account of these compounds and describe also the preparation and properties of metallic cadmium.

3. How would you estimate volumetrically the ferrous iron and oxalic acid in a solution containing both ?

4. Give some account of modern views upon the structure of the atom.

5. Explain the terms *solvent*, *solute*, *solubility*, *saturated*, *solution*, *supersaturated solution*. Give examples.

6. By the action of dilute sulphuric acid upon barium peroxide, a white precipitate and a colourless solution were obtained. On filtration, the precipitate was removed, and it was found that the filtrate would liberate iodine from potassium iodine. Explain the above reactions, and state how the formula of the substance dissolved in the filtrate has been ascertained.

No. 88

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. "Copper is more electropositive than silver." Explain this statement, and describe an experimental method by which you could arrange copper, silver, lead, magnesium, zinc and iron in descending order of electropositive character.

2. You are given a solution containing lead nitrate, silver nitrate, and mercurous nitrate. How would you obtain from it specimens of each of the three metals it contains ?

3. Describe the Mond (carbonyl) process for the extraction of nickel.

4. Describe and criticize the methods employed in the collection of gases.

5. Starting from commercial sulphuric acid, how would you prepare a specimen of pure dry hydrogen ? What tests would you apply to your specimen to discover whether it actually was pure ?

6. Discuss the equilibrium which exists between a hydrated salt and its saturated aqueous solution and between the ionized and unionized parts of the salt in the solution.

Explain the fact that salt is precipitated if hydrogen chloride is passed into its concentrated aqueous solution.

No. 89

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Explain and discuss Sir J. J. Thomson's statement that a scientific theory is a tool and not a creed.

2. Describe Ramsay and Shields' surface tension method of determining molecular weights.

3. Write a concise account of the compounds consisting of nitrogen and hydrogen only.

4. Write a short essay on valency, with special reference to (*a*) carbon, (*b*) oxygen, (*c*) argon, (*d*) nitrogen.

5. A certain solution has a P_H value of 10^{-2}. Explain this statement, and describe how you would proceed to determine the P_H value of a given solution experimentally.

6. 0·7 gramme of iron was dissolved in dilute sulphuric acid. What volume of N/10 potassium permanganate would be required to oxidize it ?

In an actual experiment it was found that 120·1 c.c. were required. Explain possible reasons for the discrepancy.

No. 90

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe and criticize the methods employed in the drying of gases.

2. Write a descriptive account of metallic nitrides, phosphides, and carbides.

3. Discuss the question whether H_2CO_3, H_2ZnO_2, H_3CCl, and $HNaSO_4$ should be regarded as acids.

4. Explain and illustrate the term *adsorption*. How has the phenomenon of adsorption been explained ? Mention any use of adsorption in chemistry.

5. Starting from ferric chloride, how would you obtain a specimen of ferrous sulphate ? Upon what evidence is the formula FeS given to a molecule of the latter substance ?

6. The decomposition of oxalic acid into carbon dioxide, carbon monoxide, and water, by means of sulphuric acid, is stated to be a monomolecular reaction. Define the term "monomolecular reaction," and suggest an experimental method of verifying the above statement.

No. 91

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What impurities are likely to be present in lead-chamber sulphuric acid. How would you (*a*) detect them, and (*b*) purify the acid from them ?

2. Give some account of the Brownian movement, and describe the apparatus which you would use to demonstrate it.

3. Explain and illustrate the term thermal dissociation. The vapour density of phosphorus pentachloride at 190° C. is 72. Calculate the percentage of dissociation.

4. How would you determine accurately the density of ammonia ?

5. Given a supply of lead acetate, how would you prepare lead dioxide from it ?
Suggest a method of determining the equivalent of lead dioxide.

6. Translate and comment upon : Elemente, welche infolge verschiedenen Energiegehaltes verschiedene Eigenschaften haben, heissen allotrop. Sauerstoff und Ozon sind also allotrope Formen desselben Elements. Der Tatbestand der Allotropie ergibt sich einerseits daraus, dass die verschiedenen Formen ohne Rest ineinander verwandelbar sind, andererseits daraus, dass gleiche Gewichte der beiden Formen mit gleichen Gewichten anderer Stoffe gleiche Produkte geben. So erhält man durch Verbindung irgendeines verbrennlichen Stoffs mit Sauerstoff oder mit Ozon durchaus übereinstimmende Verbindungen, in denen von der Verschiedenheit der beiden Arten des Sauerstoffs nichts übrig geblieben ist.

No. 92

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe the cryoscopic method of molecular weight determination, with special reference to the microcryoscopic method introduced by Rast.

2. How is cobalt obtained from its ore ? Write a concise account of the cobalt-ammines.

3. Starting from potassium hydroxide, how would you prepare (*a*) potassium chlorate, and (*b*) potassium iodide ? How would you test the purity of your products ?

4. Describe the commercial preparation of red phosphorus. How would you prepare from it (*a*) yellow phosphorus, (*b*) pyrophosphoric acid and (*c*) phosphorus oxychloride ? What is the action of water on the last ?

5. Describe, with full practical detail, how you would determine electrolytically the equivalent of (*a*) copper and (*b*) silver. State Faraday's Laws of Electrolysis.

6. When sulphuretted hydrogen is passed through a weakly acid solution of ferrous sulphate, no precipitation occurs, but if a solution of sodium acetate is added, a black precipitate of ferrous sulphide is thrown down. How do you explain this ?

No. 93

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. In what respects does the old electrochemical theory of Berzelius (*a*) resemble and (*b*) differ from the modern electrochemical theory due to Arrhenius and others ?

2. You are provided with an alloy of tin, copper and iron. How would you prepare from it (*a*) metallic tin, (*b*) cuprous oxide, and (*c*) ferric oxide ?

3. Two litres of nitrogen peroxide were found to weigh 4·07 grammes at 20° C., 750 mm. Calculate the degree of dissociation of the N_2O_4.

4. How are alloys classified ? What experiments would you make in order to ascertain in which class a given alloy ought to be placed ? Describe shortly the chief alloys of copper.

5. Describe and explain the changes which occur when a solution of potassium bisulphate is electrolysed between platinum electrodes.

6. Give some account of the evidence upon which the following formulae are based—

NH_4NO_3, ammonium nitrate ;
$COCl_2$, phosgene ;
CaC_2, calcium carbide ;
CCl_4, carbon tetrachloride.

No. 94

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. According to Prof. H. E. Armstrong, " chemical theory, to-day, is in a most destitute condition, a disgrace to our cloth, in no way congruent with our vast knowledge of fact." Express your reasoned views on this opinion.

2. What is meant by *heat of neutralization* ? Describe a laboratory method of determining the heat of neutralization of hydrochloric acid by caustic soda.

3. Given a supply of potassium chlorate, how would you prepare from it (*a*) potassium perchlorate, (*b*) perchloric acid, (*c*) chloric acid, (*d*) chlorine peroxide ?

4. What experimental evidence is there to support the following statements—

(i) When sulphur dioxide dissolves in water, sulphurous acid is formed.

(ii) When ammonia dissolves in water ammonium hydroxide is formed.

(iii) When sulphuric acid is added to water hydrates of the acid are formed.

5. Describe a method of estimating the percentage by volume of carbon dioxide in the air.

6. Translate and comment upon : Die elektrolytische Dissoziation der wässerigen Ammoniaklösung ist sehr viel kleiner, als die einer äquivalenten Kali- oder Natronlösung, und die Stärke des Ammoniaks als Base ist daher viel geringer als die der Alkalihydroxyde. In einer Lösung, welche ein Mol in zehn Litern enthält, beträgt die Konzentration des Hydroxylions nur 0·016 von der einer Kalilösung, und bei 100 l. erst 0·042. Infolgedessen wirkt eine Ammoniaklösung viel schwächer basisch als eine Kalilösung, und wird dort angewendet, wo eine solche geringere Wirkung wesentlich ist.

No. 95

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe, with examples, Thomsen's thermochemical method of finding the relative strengths of acids.

2. Explain the construction of a simple thermostat, and state the precautions which you would take to ensure its working correctly.

3. Give a short account of the metallurgy of mercury and of the oxides and chlorides of the metal.

4. Describe, with full practical detail, how you would estimate volumetrically the sodium hydroxide and sodium carbonate in a solution containing both.

5. What is meant by an *amphoteric* oxide ? Mention examples, and describe the preparation of two such oxides from the corresponding elements.

6. Translate and comment upon : Il y a donc entre le poids w d'un corps dissous dans W grammes de solvant, son poids moléculaire M et l'abaissement du point de congélation de la solution $d°$ une relation qui permet, toutes ces quantités moins une étant connues, de déterminer la quantité inconnue, et qui est donnée par la formule : $M = k \frac{w}{d\mathrm{W}}$, où k est une constante qui varie suivant le solvant considéré.

No. 96

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe the main features of the now obsolete Leblanc method for the manufacture of sodium carbonate. Explain the advantages of the modern ammonia-soda process.

2. "Metallic aluminium resists the action of water and the atmosphere not because the metal is difficult to oxidize, but because its surface becomes covered with a thin, coherent layer of oxide which protects it from further attack."

How would you demonstrate the truth of this statement? Describe the use of aluminium powder in the preparation of metals from their oxides.

3. How may the osmotic pressure of a solution be measured? How many grammes of urea must be dissolved in 1500 c.c. of water to produce a solution isosmotic at 15° C. with a 10 per cent solution of cane sugar at 25° C.?

4. Describe fully the experimental evidence upon which we believe chlorine to be an element, air a mixture and caustic potash a compound.

5. Discuss the extent and limitations of the information given by a chemical equation.

6. For what purposes is potassium permanganate employed in volumetric analysis? Criticize the various methods, given below, of making a standard solution of this substance, and explain the merits of that method which you consider the best—

(i) Weigh out accurately a suitable quantity, dissolve in distilled water and make up to a known volume.

(ii) Make up an arbitrary solution and titrate against ferrous ammonium sulphate.

(iii) Make up an arbitrary solution and titrate against ferrous sulphate.

(iv) Make up an arbitrary solution and titrate against sodium oxalate.

No. 97

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Describe, with examples, Ostwald's volume method of finding the relative strengths of acids.

2. Give some account of the general properties of colloidal solutions, and explain the terms sol, hydrosol, gel, disperse phase, suspensoid.

3. You are given a solution containing sulphuric acid and oxalic acid. How would you estimate the weight of each acid present in 1 litre of solution ?

4. Describe a quantitative method for the estimation of traces of arsenic.

5. Describe the commercial methods of obtaining chlorine, bromine and iodine.

6. Translate and comment upon : Aujourd'hui, on produit l'acide sulfurique par le *procédé de contact* qui consiste à employer un mélange d'air et d'anhydride sulfureux provenant du grillage des pyrites, et bien *débarrassé par lavage* des impuretés et des poussières (composés de l'arsenic, du phosphore, du mercure, etc.) susceptibles d'agir chimiquement ou mécaniquement sur la *mousse de platine* et de la mettre hors d'usage au bout de peu de temps. Le mélange d'air et d'anhydride sulfureux ainsi purifié et desséché arrive chaud sur l'*amiante platinée*, disposée de manière à présenter une grande surface. Une température convenablement réglée permet d'obtenir l'oxydation presque totale de l'anhydride sulfureux. L'anhydride sulfurique ainsi obtenu peut être mélangé à l'eau, ce qui donne de l'acide sulfurique concentré et pur, ou passé dans de l'acide sulfurique ordinaire pour obtenir les acides fumants.

No. 98

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. What impurities are likely to be present in commercial hydrochloric acid. How would you (*a*) detect them and (*b*) purify the acid from them ?

2. Describe, with all essential practical detail, how you would prepare from metallic aluminium specimens of (*a*) anhydrous aluminium chloride, (*b*) aluminium oxide, (*c*) potash alum, (*d*) sodium aluminate.

3. Write the formulae for (*a*) microcosmic salt, (*b*) Epsom salt, (*c*) Glauber's salt, (*d*) saltpetre, (*e*) washing soda, (*f*) baking powder, (*g*) borax.

How is microcosmic salt prepared, and what is the action of heat upon it ?

4. Describe, with full practical detail, how you would estimate volumetrically the sodium carbonate and sodium bicarbonate in a solution containing both.

5. Describe, with full practical detail, the cryoscopic method of molecular weight determination.

6. Define the terms *atomic volume* and *molecular volume*. What light is thrown on chemical composition by a consideration of molecular volumes ?

No. 99

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write a short historical account of the development of the idea of chemical purity.

2. Ordinary "zinc dust" consists of a mixture of zinc and zinc oxide. Describe an accurate method of estimating the percentage by weight of zinc present.

3. How does boron occur naturally? How may the element be prepared from borax?

4. Give some account of the relation between chemical constitution and physico-chemical properties, e.g. molecular volume, refraction equivalent, etc.

5. Suggest methods of separating from one another the constituents of each of the following mixtures: (*a*) sulphur and red phosphorus; (*b*) oxygen and hydrogen; (*c*) nitric oxide and nitrous oxide; (*d*) carbon, manganese dioxide and reduced iron; (*e*) silica and alumina.

6. How is sodium peroxide obtained on the large scale? How would you demonstrate that the constitution of this substance is Na_2O_2?

Mention the principal properties and uses of sodium peroxide.

No. 100

Read the question carefully and see that your answer contains no irrelevant matter. Numerical problems should be checked, since arithmetical errors are heavily penalized.

1. Write an essay on the action of the halogens upon metallic hydroxides and oxides.

2. Describe, with full practical detail, how you would estimate volumetrically the strength of a given solution of potassium chlorate.

3. Write a concise essay on the Periodic System, with special reference to (*a*) its merits, and (*b*) any anomalies it may present.

4. State the *Law of Isomorphism* and explain and illustrate its use in the determination of atomic weights.

5. What do you mean by the strength of an acid ? How may the strengths of two acids be compared ?

6. Translate and comment upon : L'acide azoteux n'est intéressant que par les sels métalliques qu'il donne et qui ont le nom d'azotites. Celui d'ammonium, décomposé par la chaleur, dégage de l'azote pur. On obtient l'acide azoteux par le dédoublement du peroxyde d'azote en acide azoteux et acide azotique au contact de l'eau à 0°. Pour cela on laisse tomber goutte à goutte le peroxyde d'azote froid dans de l'eau à 0° ; il se produit de l'acide azoteux, liquide bleu qui tombe au fond de l'eau ; celle-ci dissout l'acide azotique formé et reste incolore. La dissolution étendue d'acide azoteux est assez stable pour qu'on puisse la chauffer sans la décomposer. Elle joue le rôle de corps oxydant *vis-à-vis* des composés oxydables, comme l'acide sulfureux et les sels ferreux ; elle oxyde l'iodure de potassium en donnant de la potasse et de l'iode. Elle est, au contraire, réductrice, quand on la fait agir sur les corps qui cèdent facilement leur oxygène ; ainsi elle réduit les sels d'or et les sels de mercure en mettant le métal en liberté.

PRINTED IN GREAT BRITAIN AT THE PITMAN PRESS, BATH
B8—(1254)